

Fiber laser applications for free space optical links

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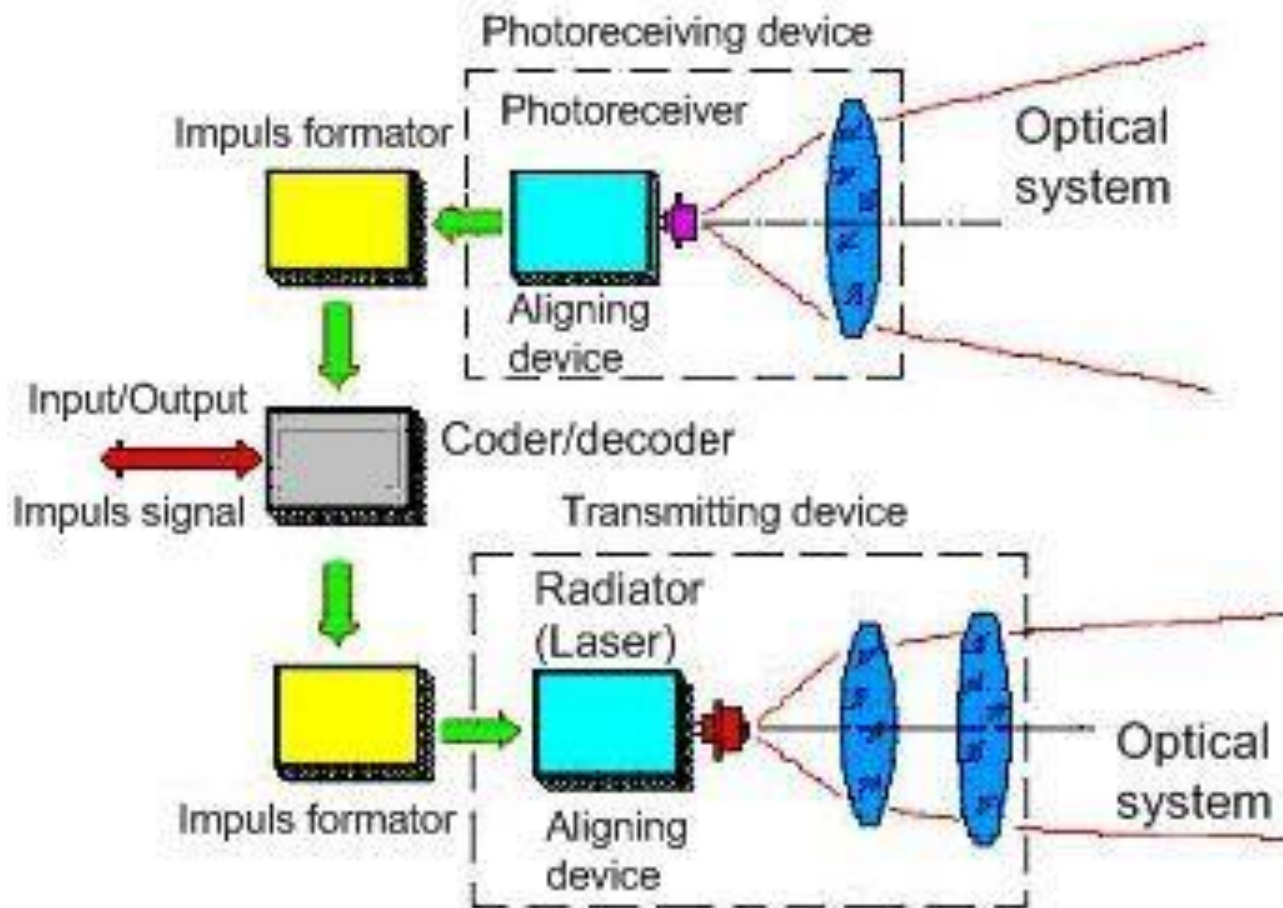
Introduction

- The free space optical links are widely used for information transmission.
- One of its important applications is in healthcare when people with serious health problems have to be under continuous survey and control.
- The free space optical links have a big advantage because they can be operated without licenses.

The role of fiber laser

- In the free space optical links there is a need for high transmitter power.
- However, the widely used semiconductor lasers usually cannot provide sufficient power for that purpose.
- Therefore the fiber laser could be a proper candidate in this respect.

Block diagram of free space optical (FSO) links



Advantages of FSO links

- Licence-free operation (in contrast with radio links)
- Easy and fast deployment
- Frenel zone cleanliness is not necessary
- Protocol transparency
- High bit rates
- Low bit error rates (BER)
- Immunity to electromagnetic interferences

Characteristics of FSO links

- Line-of-sight propagation: obstacles
- Last mile connection: limit 2 km
- No area coverage: point-to-point link
- Full duplex operation
- Health hazard, eye safety
- High security when working with narrow beam(s)

Security

- FSO is a very secure information transmitting method.
- The laser beam cannot be detected with a spectrum analyzer or RF meter.
- The infrared laser beam is invisible which makes it hard to find.
- The laser beam used to transmit data is very narrow.
- This means that it is almost impossible to intercept the data being transmitted.

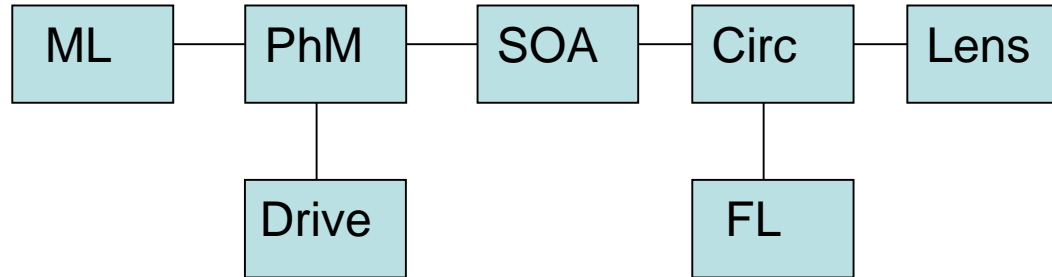
Information transmission

- The optical beam has to be modulated by the information to be transmitted.
- However, the modulation capability of fiber lasers is very limited.
- Direct modulation can be done only with small bit rates.
- External modulation would be the other choice.
- However, the well established Mach-Zehnder or other optical modulators can not tolerate the high power of fiber lasers.

Fiber laser transmitter I.

- A system is now proposed which offers simultaneously high output power and high speed modulation capability utilizing fiber lasers.
- For that purpose the injection locking technique is used.
- The modulation is carried out on the beam of a master laser and the modulated signal is injected into the fiber laser providing a modulated high output power.

Fiber laser transmitter II.



Master laser (ML)

- low noise
- high stability
- single mode
- small power

Phase mod (PhM)

- linear modulation
- wide band
- low loss

SOA

- constant gain
- constant phase
- low noise

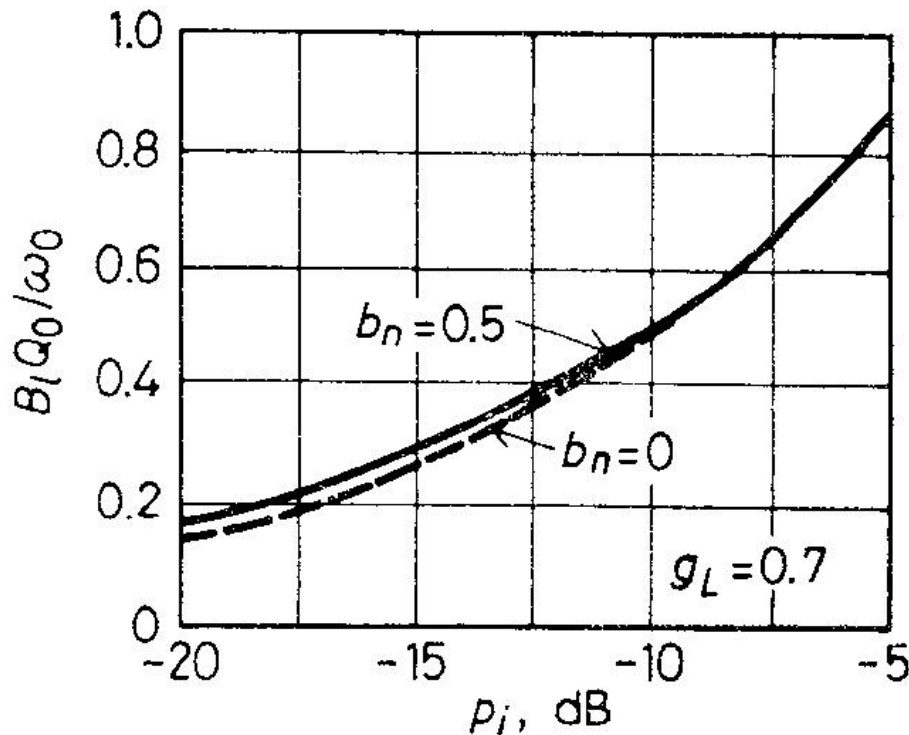
Fiber laser (FL)

- high power
- locking band
- phase shift
- AM compression

Injection locking properties

- Locking band: in this band the injected signal controls the wavelength of the fiber laser.
- The phase of the output signal follows the phase of the injected signal
- The output power of the injection locked laser is practically not dependent on the injected power.
- The laser wavelength has to be kept in the center of the locking band by an optical phase locked loop using „sample and hold” technique

Locking band versus input power



Q_0 = unloaded quality factor

b_n = nonlinearity factor

g_L = load

Locking band is obtained as:

$$\frac{B_l}{\omega_0} = \frac{2}{Q_L} \sqrt{\frac{p_i}{p}}$$

B_l = locking band

ω_0 = angular frequency

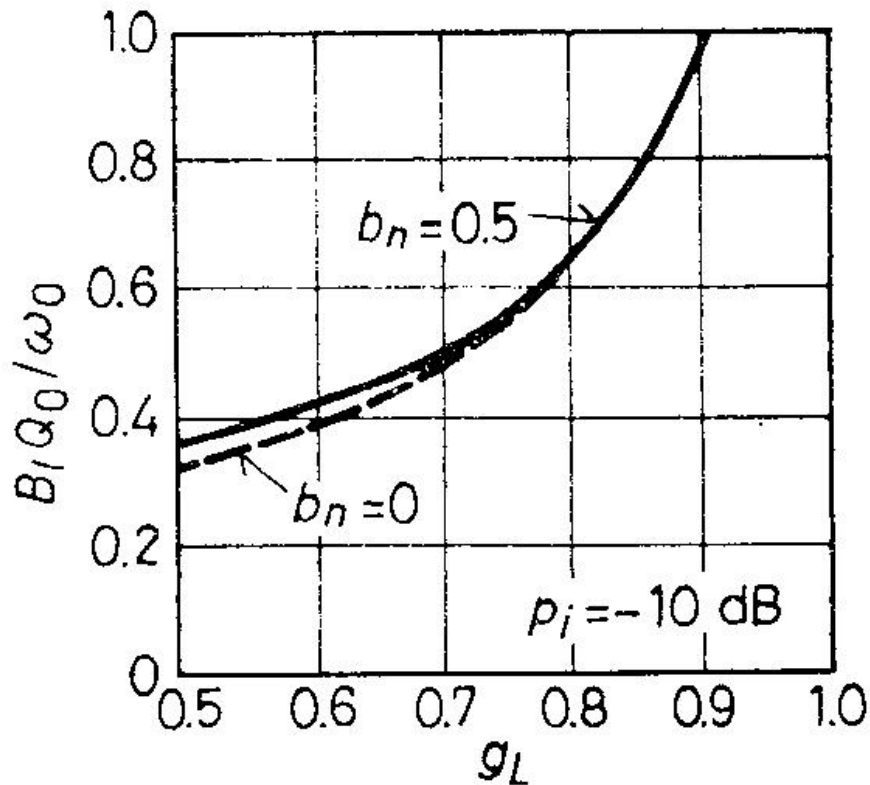
Q_L = loaded quality factor

p_i = injected power

p = output power

Normalized quantities are used

Locking band versus load



B_l = locking band

ω_0 = angular frequency

Q_0 = unloaded quality factor

b_n = nonlinearity factor

p_i = injected power

g_L = load

Normalized quantities are used

Range limiting factors

- Fog (10 to ~100 dB/km attenuation)
- Beam dispersion
- Atmospheric absorption
- Rain
- Snow
- Terrestrial scintillation
- Interference from background light sources
- Sun shine
- Shadowing
- Pollution / smog
- Pointing stability in wind

Applications

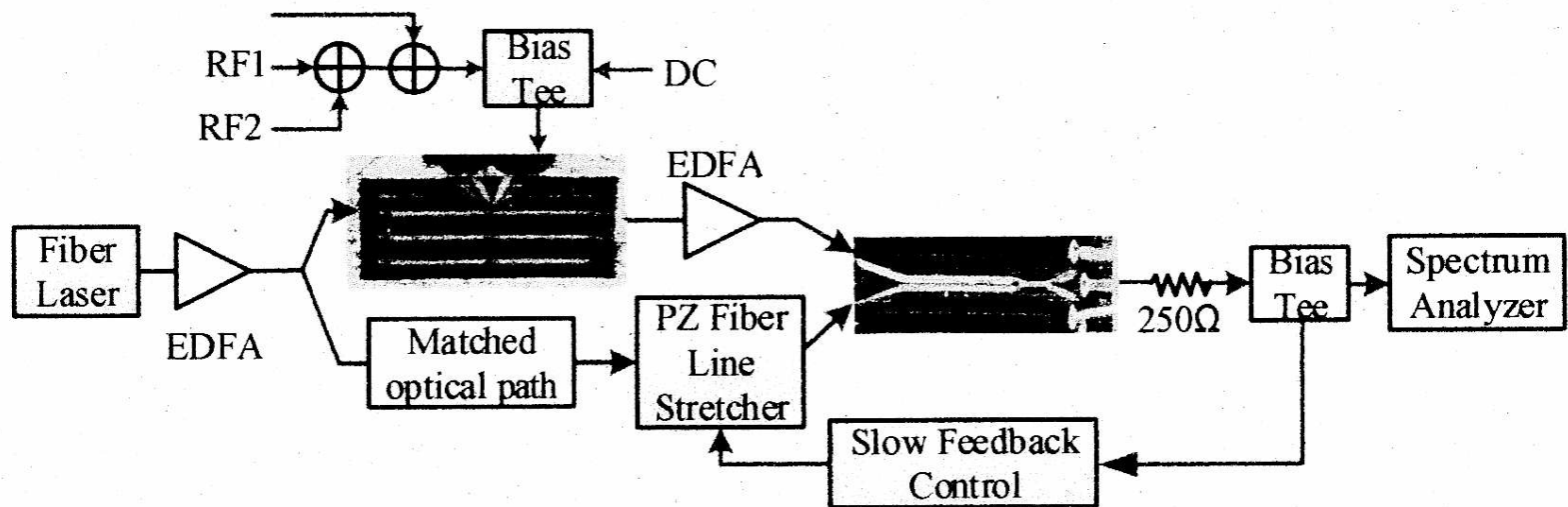
- One of its important applications is in healthcare when people with serious health problems have to be under continuous monitoring and control.
- The signals of patient's sensors are forwarded to a concentrator via radio waves and the concentrator is connected to a health center by free space optical link.
- That method is well applicable when „ad hoc” connections are needed.

Further applications

- Speedy service delivery of high-bandwidth access to optical fiber networks
- Temporary network installation (for events or other purposes)
- Reestablish high-speed connection quickly (disaster recovery)
- To cross a public road or other barriers
- An alternative or upgrade add-on to existing wireless links
- A safety add-on for important fiber links (redundancy)
- LAN-to-LAN connections on campuses with high speeds
- LAN-to-LAN connections in a city, a metropolitan area network

Recent research publication

LONGTAO XU, SHILEI JIN, AND YIFEI LI: “Down-conversion RF/photonic link with a monolithically integrated ACP-OPLL phase demodulator”,
OPTICS EXPRESS, Vol. 25, No. 18, pp. 21705-21710, 4 Sep 2017



Fiber laser source in an optical phase modulation experiment

Conclusions

- The free space optical links have a big advantage because they can be operated without licenses.
- The fiber laser can be used for providing a high transmitter power in these links.
- An important application is in healthcare when people with serious health problems have to be under continuous monitoring.

Thank you for your attention